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CUES, FEEDBACK AND TRANSFER IN UNDERGRADUATE PILOT TRAINING.(U)
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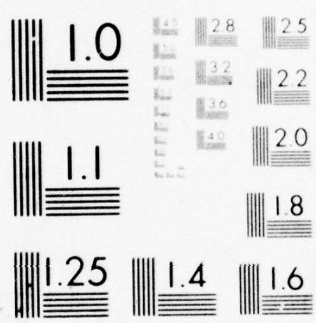
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FINAL REPORT

Vernon S. Gerlach

August 1975

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Office of Scientific Research
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Department of Educational Technology
Arizona State University
Tempe, AZ 85281

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Arizona State Universtiy
Tempe, Arizona

August, 1975

CUES, FEEDBACK AND TRANSFER IN UNDERGRADUATE

PILOT TRAINING

Cues, Feedback, and Transfer in Undergraduate Pilot Training

- Final Report -

I. Overview

Existing knowledge in the behavioral sciences often fails to provide an adequate base for the design of specific training programs in which the acquisition and maintenance of complex perceptual-motor skills is an expected outcome. The research conducted during this project represents a systematic effort to generate prescriptive statements or guidelines for designing effective training materials and procedures for undergraduate pilot training in both simulated and natural environments. A series of studies was conducted in which selected dependent variables related to instructional cues, feedback, and transfer were studied as they affected flying training.

Results of this series of studies provided a basis for the development of a model for generating instructional cues based on a set of procedures for an objective task analysis. Further studies were then conducted for the purpose of demonstrating the effect of such systematically generated cues. Finally, the generalizability of the effect of such systematically generated cues was observed to determine the effects of amount of practice during cue learning and type of instructional cue.

A substantial research effort, concomitant with the above, was devoted to the problem of developing objective and automated procedures for measuring complex flying skills in an advanced simulator.

II. Work Accomplished

Phase I (18 July 1971 through 31 August 1972)

Definition of subject area; review of literature.

Higgins, N. E., "Feedback in Group Instruction," February, 1972. Technical Report No. 20201. Much of the research on feedback in cognitive learning tasks is of limited applicability in designing instructional products. Studies using systematically designed instructional sequences to investigate feedback variables were reviewed.

An analysis of the feedback literature relevant to instructional situations suggests several variables whose further study may contribute to the design of more effective instructional products. These variables include (1) the amount of information contained in the feedback stimulus, (2) frequency of feedback, (3) immediacy of feedback used, and (4) the interaction between feedback and incentives for acceptable performance.

Literature related to each class of feedback variables is reviewed and suggestions for future research described.

Clark. M. C., "Aspects of transfer that relate to the development and design of instructional materials," February, 1972. Technical Report No. 20202. This report develops the following five points and suggests applications of each to the instructional design process:

1. Establishing approach tendencies seems to be a rather clear cut task. Guidelines for establishing approach tendencies exist in clearly useable form. They simply need to be used with respect to producing positive transfer.

2. Learning to learn for the instructional designer deals with consolidating heuristics pertinent to the establishment of learning sets and teaching the learner to learn. At this point, the literature provides many leads for the derivation of such heuristics. The task seems to be one of simply consolidating ones available in the literature into a clear concise verbal statement.

3. Transformation of the nominal stimulus into the functional stimulus seems to be an important area for investigation. Lawrence (1963) has indicated that a long-line of work by himself and Sutherland and others on encoding types of responses tends to relate what psychologists have referred to as the transformation of the nominal stimulus to the functional stimulus. It seems that much of what has been derived out the paired-associate learning studies with respect to transfer might be far more generalizable and far more reliable if we could deal with properties of the functional stimulus as opposed to properties of the nominal stimulus. The area of mathemagenics as discussed by McDonald (1968) and Rothkopf (1965) probably relates to the type of encoding discussed by Lawrence.

4. Analysis based on response categories deals with the limitations of transfer to certain classes of responses. Gagne (1971) and Merrill (1971) have identified response classes similar to some of Melton's categories of learning (Melton, 1964). It seems as though a usable system for producing transfer will have to consider these classes of responses. Different rules for transfer will probably apply as a function whether the learning tasks are in the same response category. Relationships between rules of transfer may be predictable as a function of relationships between response classes (Merrill, 1971).

5. Effects of transfer with respect to individual differences must be considered. We have reason to believe that materials which emphasize learning to learn might result in reducing the affects of individual differences in certain training situations. A more thorough search of literature on individual differences should shed some light on this issue. In any case, it seems that heuristics designed to produce training materials optimizing on transfer affects should consider individual differences within an apptitude by treatment inter-action framework. This argument seems exceptionally strong in the case of pilot training where frequently the tolerances in terminal behavior are small.

Roberts, K. C., and Taylor, C. L., "The Instructional Cue," February, 1972. Technical Report No. 20203. Educational technology is primarily concerned with the application of valid principles of science to the

development of instructional programs. Many of the principles available for use have originated in experimental psychology. The purpose of this paper is to review literature relevant to the specification of the stimulus, specifically the instructional cue, in instruction programs. The instructional cue and related concepts are defined. The application of the instructional cue is described in summaries of research reports dealing with this concept.

Generally, stimuli are defined as events which are external to the learner. They are events in the environment which confront the learner; he attends to some. In an instructional setting there are a vast number of stimuli to which the learner can attend. Since the term stimulus can represent any of this vast number, precise terminology is needed. Operationally defined terms facilitate the replication of research procedures. Replication, under precisely controlled conditions, permits the evaluation of contradictory findings. Precise definitions also permit researchers and designers in applied settings to evaluate basic research in terms of its applicability to real-time instructional or training problems.

<u>Selection of independent and dependent variables for initial experiments</u>.

Initial efforts in this segment of Phase I centered on a specific effort to design a setting in which the effects of various levels of the independent variable "instructional cue," as defined in the literature review cited above, could be observed, and which would, at the same time, serve as a vehicle for studying feedback and transfer.

The Air Force <u>ATC Syllabus P-V4A-A</u> (T-41/T-37/T-38) was systematically analyzed in order to enable us to identify maneuvers which possess the following characteristics: (a) precise objective measurement of performance; (b) potential for high degree of transfer to other tasks; (c) significant (i.e., "important") for USAF. Whenever a tentative conclusion was formed, it was submitted to the professional staff of HRL at Williams Air Force Base, through Dr. W. V. Hagin, for critical review.

Next, the instructional task Vertical-S was examined in terms of current practices. Following discussion with various USAF officers at the instructional decision-making level as well as consultation with colleagues at the University of California at Berkeley and at New Mexico State in particular, a questionnaire was developed to enable us to determine what components of the flying training curriculum are most important to (a) instructor pilots and (b) student pilots. Results of this aspect of the project have been described in Technical Report No. 21129: Brecke, F., and Reiser, R., "Critical components of flight instruction as perceived by IPs and SPs," November, 1972.

As a result of this activity, it was tentatively decided to use the Vertical-S as the instructional task, rather than other candidate tasks dealing with such areas of concern as, for example, the traffic pattern or navigation. At this stage of the project, the Vertical-S maneuver seemed to be a highly acceptable vehicle for observing our independent variables and their effect(s). The Vertical-S is (a) a well-defined task,

(b) relatively simple to measure when mastery is attained, (c) a maneuver incorporating a fair range of skills, and (d) a task which can be learned in a simulator.

Concurrently, a detailed task analysis of the maneuver Vertical-S was completed. This analysis included a study of instructor pilots' oral instruction regarding Vertical-S. These briefings were recorded, and the typed transcripts were analyzed to ascertain the quantity and quality of instructional cues being used in current undergraduate pilot instruction. The analyses showed that in spite of all efforts at standardization, this kind of oral instruction exhibits extreme variability with regard to number, completeness, and type of cues, type of instructional approach (lecturing or questioning), and structional coherence. A detailed account of this aspect of the project is found in Technical Report No. 21201: Brecke, F., and Gerlach, V., "Model and procedures for an objective maneuver analysis," December, 1972.

Further analyses of current instructional practice were conducted to determine the role of instructional cues in audiovisual materials and in video recordings of in-flight instruction.

Development of instructional product.

In view of the fact that Air Force materials do not, to the best of our knowledge, exhibit any systematic application of that powerful stimulus which we refer to as the instructional cue, our next task was to determine the most effective manner of relating good current AF instruction to our model. To put it differently, we have seen that in other areas, such as developing materials for teaching reading or for teaching adults to produce effective motion picture films, the instructional cue is a powerful variable which can serve to increase the effectiveness and/or efficiency of instructional products.

In the present project, Lt. Col. Robert Morris of WAFB provided invaluable suggestions for linking good current practice with the variables under investigation.

First, his view of undergraduate pilot training involves the learner in an information-gathering and information-translating process. The instructional cue, as used heretofore, had not been developed with any degree of emphasis on this dimension; consequently, our research was designed to use information-theory-based principles to make cue-generation more effective.

Second, this approach enabled us to capitalize on the potential of two powerful models developed in our laboratory: the Instructional Specification, or IS (Gerlach, V. S., Baker, R. L., Schutz, R. E., and Sullivan, H. J., Defining Instructional Specifications, Inglewood, CA: Southwest Regional Laboratory for Educational Research and Development, 1967) and the INDOC classification system for behavioral outcomes (Gerlach, V. S., and Ely, D. P., Teaching and Media, Englewood Cliffs, NJ: Prentice-Hall, 1971. Ch. 3).

Third, application of these principles enabled us to generate and refine a set of rules for producing cues and cue sequence. These systematically-generated cues were eventually incorporated into an instructional product and variations of the product were developed to enable us to study feedback and transfer.

Phase II (1 September 1972 through 20 August 1973)

Definition of subject area; research efforts.

Four technical papers were published during this phase:

Reiser, R., Brecke, F., and Gerlach, V., "On the difference between procedure and technique in pilot instruction," November, 1972. Technical Note No. 21128. Procedure provides information about flight parameters (numerical values such as air speed, vertical velocity, etc., for a particular maneuver). Technique, on the other hand, consists of information on how to observe and manipulate the controls of the aircraft so that the desired flight parameters can be attained. Technique is concerned with cues for appropriate motor behavior. Procedure tells what to do and technique tells how to do it.

Procedure can be found recorded in books and other self-instructional material. The student can, and often is required to, learn procedures on his own. Technique, however, is not found in books. It seems to be part of pilot "lore" and is passed on from the instructor pilot to the student pilot via word of mouth, either during the briefing or while in the aircraft or both.

Brecke, F., and Reiser, R., "Critical components of flight instruction as perceived by IPs and SPs," November, 1972. Technical Report No. 21129. A complex and exacting aerial maneuver used by the Air Force during flight training programs was needed in order to permit the assessment of the effect of various levels of instructional cues. Research was carried out in an effort to ascertain whether Instructor Pilots and Student Pilots agreed with the researchers concerning the difficulty and cruciality of various components of flight training in general and of the Vertical S-A maneuver in particular. Eighty-two Instructor Pilots and 50 Student Pilots from Williams Air Force Base, Arizona were each given a questionnaire to elicit their opinions concerning various instructional aspects of light training. There was general agreement among the subjects concerning the difficulty, cruciality, and need for instructional improvement in the areas of "traffic pattern" and "instruments". Since the Vertical S-A is predominantly a component of "instrument" flying, it was decided to use it as the vehicle within which the dependent variable "instrument flying skill" would be observed.

Brecke, F., and Gerlach, F., "Model and procedures for an objective maneuver analysis," December, 1972. Technical Report No. 21201. A large segment of Air Force pilot training consists of teaching complex and precise aerial maneuvers, each of which can be broken into constituent instructional parts. This paper presents a conceptual model, called a Maneuver Analysis, for breaking a maneuver into instructional parts. The

process of generating the instructional parts was used with a specific instrument maneuver, the Vertical S-A. The researchers developed a general model consisting of three critical components, 10 analytic points, and a set of four "standard questions" which can be used for generating Maneuver Analyses. The model provides a comprehensive Maneuver Analysis of the Vertical S-A maneuver and should be well-suited to similar aerial maneuvers.

Gerlach, V., Brecke, F., Reiser, R., and Shipley, B., "The generation of cues based on a maneuver analysis," December, 1972. Technical Report No. 21202. Instruction at present is rarely characterized by the presence of systematically generated instructional cues. This report presents a model for generating powerful instructional cues and illustrates the use of the model by means of a practical example taken from the Air Force's undergraduate pilot training curriculum. The Vertical S-A, a precise and exacting aerial maneuver, was used to demonstrate a Maneuver (Task) Analysis and subsequent cue generation. The model provided clear and comprehensive systematically generated instructional cues for the Vertical S-A maneuver.

Experimental work.

Development of Design. On the basis of analytical and observational work during Phase I of this project an experiment was developed to test the effects of systematic variations in the level of the independent variable "Instructional Cue" (IC). First we developed a precise operational definition of the variable in order to permit us to analyze existing instruction in terms of the variable. Concurrently, we developed a semi-algorithmic design for new instruction with definable levels of the variable. These activities resulted in the definition of three levels of cues and two modes of instructional presentation/delivery which were tested in the nine different combinations shown in Figure 1.

The two modes of presentation correspond to current instructional practice in UPT. Student pilots are expected to prepare themselves for in-flight instruction by studying the appropriate sections in manuals AF 51-37, Instrument Flying, and ATC 51-4, Primary Flying, Jet. In addition, they receive an oral briefing just prior to actual in-flight practice. The design thus permits testing of specified levels of the variable IC as well as of interactions of this variable with the two primary modes of instruction currently in use. The first experiment was exploratory in nature, i.e., it was anticipated that it would yield a maximum amount of information concerning the variable of primary interest and the feasibility of the design, without excessive expenditure of money, time, and experimental effort. We, therefore, decided to limit our observations to the three diagonal cells and to use the results as a basis for deciding whether future experimental work should include any or all of the remaining six cells.

Level A of the independent variable (IC) was a sample of cues as they are currently administered either via current AF manual or via current AF briefing. The quantity as well as the quality of the cues

M: CSC B: CSC	M: CSC B: SDC	M: CSC B: OO
M: SDC B: CSC	M: SDC B: SDC	M: SDC B: OO
M: OO B: CSC	M: OO B: SDC	M: OO B: OO

Presentation Mode:	M:	Manual (i.e., textual)
	B:	Briefing (i.e., oral)
Level of Cues:	CSC:	Current standard cues (as presently used in UPT)
	SDC:	Systematically developed cues (on the basis of the maneuver analysis)
	OO:	Objective only (no instructional cues, but a precise textual presentation of the desired terminal behavior)

Figure 1: Experimental Design

included in this treatment were to reflect current standard instruction, which was characterized as intuitively developed, as closely as possible.

Level B was composed of cues which were systematically developed by means of a semi-algorithmic procedure. One component of this procedure is the maneuver analysis as described in Technical Reports (Gerlach, Brecke, Reiser, & Shipley, 1972; and Brecke & Gerlach, 1972).

Level C, no instructional cues at all, was included because we speculated that the student pilot left to his own devices may learn quite efficiently as long as he has a clear idea of the goal performance he is to attain. Additional verbal information beyond the goal setting objective may be mere noise and thus non-facilitating if not inhibiting.

Development of Treatments. Treatments on each level included two components: a textual (typewritten) "Manual" and an oral briefing. In order to eliminate any Instructor-Treatment interaction, a recorded TV presentation was used for the briefing portion rather than a live instructor. The videotape was prepared by taping an instructor pilot from a unit different from the units that furnished Ss for the experiment.

Treatment A: The manual component of this treatment condition consisted of a typed copy (one-half page, single spaced) of the section "Vertical S" from the USAF ATC Manual 51-4. This text contains general rather than specific information and only seven instructional cues. The script for the TV presentation of the briefing was constructed as follows: Eight flight-line briefings on the Vertical S were covertly recorded on audio tape and subsequently transcribed on paper. Four raters independently identified the instructional cues. Interrater reliability exceeded .80. The cues identified by each rater were then tabulated by maneuver segments and cue content. Representative cues from each class were drawn randomly from the population of identical or highly similar cues. The mean total number of cues and the mean number of cues per segment were the same for both the taped briefings and the constructed briefing. (See Appendix A for tabulation of the eight briefings.)

Treatment B: The manual and the briefing components for this treatment condition were identical. The instructional cues contained in the text were developed on the basis of a maneuver analysis as described in detail in Brecke & Gerlach (1972). This maneuver analysis specifies three classes of information for each maneuver segment. The procedure is replicable and generalizable to other maneuvers. On the basis of the comprehensive and precise information compiled in the maneuver analysis, a team of one subject matter expert and one instructional development expert designed a minimal set of cues based on a set of simple rules in question form. The resulting list of cues underwent four revision cycles, during which instructor pilot judgments generated during actual maneuver performances were analyzed and incorporated. The latter procedure is replicable and generalizable.

Treatment C: Both the manual and the briefing component of this treatment contained only the maneuver objective (which was included in

the other two treatments as well). No instructional cues whatsoever were included.

A complete comparison of the treatment conditions is shown in Table 1. (See Appendix B for the texts of the Treatments.)

Experimentation. Actual experimentation was carried out in the facilities of the Air Force Human Resources Laboratory at Williams AFB. The investigators received outstanding cooperation from the personnel at this facility. Subjects, equipment, and expertise were made available to us in spite of HRL's existing heavy research commitments.

Subjects. Ideally subjects were to satisfy three conditions:

(a) From the same population to which the findings of the study were to be generalized, i.e., UPT students.

(b) No prior flying experience except UPT.

(c) At a point in the UPT curriculum just prior to the first trainer mission featuring the Vertical S-A.

It was possible to obtain 11 subjects fulfilling requirements (a) and (c). All other potential subjects who would have satisfied all those requirements were participating in an HRL experiment. The risk of contaminating either experiment would have been too great if some subjects would have participated in both. The 11 subjects had varying amounts of prior flying experience. The random assignment to one of the three treatment conditions resulted in the following distribution: A-4; B-4; C-3.

Apparatus. For the pretest as well as for the learning trials a T4-G flight simulator was used. The simulator was modified (TV capability off, motion off) to correspond with the normal T4 trainer with which the subjects were already familiar.

Subject performance as defined by observed trainer flight parameters was recorded in 2 second intervals by means of an Incre-Logger, Model 4434, an automatically triggered cassette tape-recorder.

For the TV presentation of the briefings, a standard 19" playback unit was set up in an isolated study carrel.

Procedure. Data was collected from 6-4-73 to 6-6-73 during normal duty hours. Subjects reported at the experimental facility and first read a one-page orientation. They asked no questions and requested no additional explanations. Each subject then "flew" the simulator from the student seat (left) for 5 minutes of straight and level flight under simulated mild rough-air conditions. After this pretest, each subject went through the instructional session in an adjacent building. The instructional session consisted of (1) reading the manual "until completely understood" and (2) viewing the TV presentation of the briefing. The time for reading the manual was recorded. Immediately upon completion of this session, the subject returned to the simulator and performed eight

CONDITION		CONTENT VARIABLES	A	B	C	REMARKS
MANUAL	1.	Maneuver objective	✓	✓	✓	Same
	2.	Advance organizer	-	✓	-	General preparatory cue, 1 paragraph
	3.	Number of cues	7	23	-	Marginal overlap A-B
	4.	Type of cues	F G	F G S	-	D = dysfunctional F = funct., G = general, S = specific
	5.	Chronological sequence	✓	✓	-	Roughly chronological
	6.	Irrelevancies, transit. mat.	✓	✓	-	Minimal in both! No appreciable difference
	7.	Summary cues	-	6	-	
BRIEFING	1.	Introductory paragraph	✓	✓	✓	a. Purpose b. Maneuver objective
	2.	Advance organizer	-	✓	-	
	3.	Number of cues	19	23	-	B: Manual & Briefing identical
	4.	Type of cues	D G S	F G S	-	A: Manual & Briefing: marginal overlap
	5.	Chronological sequence	✓	✓	-	
	6.	Irrelev., transit. mat.	✓	✓	-	Minimal in both! No appreciable difference
	7.	Summary cues	-	6	-	

Table 1: Comparison of the Treatments

trials of the Vertical S-A maneuver. Each trial lasted about 2-1/2 minutes, with one minute rest between trials. After the eighth trial, the subject was asked to complete a questionnaire designed to assess his reactions to the experiment. He was then dismissed.

Data Recording. The prime requirement for an objective performance evaluation is the capability for monitoring the relevant aircraft parameters with a high degree of resolution and at time intervals which are short enough to obtain a complete performance history. Several commercial firms manufacturing equipment capable of multichannel recording at intervals of 2 seconds or less were contacted after it was learned that none of the AFHRL laboratories could furnish hardware with the desired capabilities. Incre-Data Corporation of Albuquerque provided the most economical and most convenient solution. Their Model 4434 Incre-Logger was connected to eight of the T4-G analog output signals representing the dependent variables of interest. The Incre-Logger converted the analog signals to digital form in an 8-bit binary format. The converted data was recorded on a cassette type precision data tape.

The recorder scanned the data channels every two seconds, recording time in minutes and seconds as well as a standard input reference channel. Approximately 90,000 data points were recorded for the 11 Ss participating in the experiment. The variables of concern (in addition to time) were:

1. Airspeed in knots per hour;

2. Heading in degrees with 360 degrees as the standard initial reference point;

3. Vertical velocity in feet per minute;

4. Pitch in degrees plus or minus;

5. Altitude in feet;

6. Bank in degrees left or right (plus or minus);

7. Elevator deflection, plus or minus in 1-bit increments;

8. Throttle as percent of maximum power.

The data was recorded on the tape sequentially in a linear pattern across scans and scans across trials, trials across subjects. After completion of the experiment, the data was transcribed from the cassette tape to a standard high speed computer tape in an appropriately coded format. It was necessary to write a Fortran computer program to unpack, sort, and rescale the binary data. The functions determining the characteristics of the T4-G electrical signals and the recording capabilities of the Incre-Logger were combined to obtain the desired mathematical functions used to rescale the data to numerical (decimal) values equivalent to those observed on the instruments by the pilot. A data display

capability on the Incre-Logger enabled the researchers to crosscheck computed against actual observed values.

Data Processing and Reduction. The transcription of the raw data from the cassette tape to a standard high-speed computer tape was handled by Incre-Data Corporation. All further processing was accomplished at the computer center of ASU. The programming effort for the unpacking and rescaling of the data was considerable. No operational canned programs were available in the system library. The program, created by the investigators, can now be used for any future task of this nature.

A printout of the raw data in the form of actual instrument readings for variables 1 through 6 was obtained. This printout represents a complete performance history for each subject over the pretest and eight post-instructional practice trials.

The raw data were subjected to a primary reduction in terms of raw score means and error means. A secondary reduction was the derivation of percent-time-on-criterion scores for three different criterion bandwidths. A summary of the reductions is shown in Table 2.

A summary of percent-time-within-criterion values is shown in Table 3.

Phase III (21 August 1973 through 17 August 1974)

Definition of subject area; research efforts.

Three technical papers were published during this period:

Wagner, B., "Figural instructional cues as mediators of rule learning," February, 1973. Technical Note No. 30216. A two stage transfer paradigm was used to investigate three areas of rule learning: (1) Venn diagrams as transformational mediators; (2) ease of learning the complementary rules, biconditional and exclusive disjunction; and (3) effect of constructed versus multiple-choice Venn diagrams on transfer. The results indicated that the use of Venn diagrams in prior training significantly ($P = .004$) facilitated the learning of a new rule on the transfer task. However, no significant difference was found between constructed versus multiple-choice Venn diagrams, and no significant difference was found in the difficulty of learning the two complementary rules, biconditional and exclusive disjunction.

Gerlach, V. S., & Brecke, F. H., "Algorithms for learning and instruction: Generating instructional cues," February, 1973. Technical Note No. 30217. During the past decade, scholars in Germany, Great Britain, and the Soviet Union have published a substantial amount of material dealing with the application of algorithms and algorithmic procedures to instruction. This paper reviews the most significant European concepts, describes what is being done in the U. S., and identifies problems worthy of serious research endeavors. An algorithm is a list of unambiguous elementary instructions specifying a sequence of discriminations and operations which will yield the solution to any problem of a class. Algorithms may vary in the degree to which they are deterministic.

	AIRSP.		HEAD.		VERT.V		ALT.		PITCH		BANK	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
A. Means of raw scores												
a) By S and trial	✓	✓										
b) By S over trials 1-8	✓	✓										
c) By Group and trial	✓	✓										
d) By Group over trials 1-8	✓	✓										
e) Grand means	✓	✓										
B. Means of error scores												
a) By S and trial	✓	✓	✓	✓								
b) By S over trials 1-8	✓	✓	✓	✓								
c) By Group and trial	✓	✓	✓	✓								
d) By Group over trials 1-8	✓	✓	✓	✓								
e) Grand means	✓	✓	✓	✓								
C. Area scores												
a) By S and trial	✓	✓										
b) By S over trials 1-8	✓	✓										
c) By Group and trial	✓	✓										
d) By Group over trials 1-8	✓	✓										
e) Grand means	✓	✓										
D. % Time on criterion I												
a) By S and trial	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
b) By S over trials 1-8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
c) By Group and trial	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
d) By Group over trials 1-8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
E. % Time on criterion II												
a) By S and trial	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
b) By S over trials 1-8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
c) By Group and trial	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
d) By Group over trials 1-8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
F. % Time on criterion III												
a) By S and trial	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
b) By S over trials 1-8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
c) By Group and trial	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
d) By Group over trials 1-8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 2: Percent-time-on-criterion Scores

Group Means: Time within Criteria (Band 1)
Trials 1 through 8

	A	B	C
Airspeed ($\pm$ 1 KIAS)	16.42	19.32	17.52
Heading ($\pm$ 1^o)	11.71	12.25	14.30
Vertical Velocity ($\pm$ 50 ft/min)	15.82	13.99	9.27
Pitch ($\pm$ 5^o)	12.81	12.35	12.43
Altitude ($\pm$ 50')	61.87	40.85	36.31
Bank ($\pm$ 1^o)	7.25	5.19	6.27

Group Means: Time within Criteria (Band 2)

	A	B	C
Airspeed ($\pm$ 2 KIAS)	31.90	36.98	33.69
Heading ($\pm$ 3^o)	33.19	35.04	40.43
Vertical Velocity ($\pm$ 100 ft/min)	30.85	27.48	18.33
Pitch ($\pm$ 1^o)	25.27	24.39	24.54
Altitude ($\pm$ 75')	73.25	56.75	45.48
Bank ($\pm$ 3^o)	21.48	15.45	18.64

Group Means: Time within Criteria (Band 3)

	A	B	C
Airspeed ($\pm$ 5 KIAS)	67.00	72.63	67.64
Heading ($\pm$ 3^o)	50.35	53.60	60.73
Vertical Velocity ($\pm$ 150 ft/min)	44.43	40.03	26.98
Pitch ($\pm$ 1.5^o)	37.08	35.82	36.04
Altitude ($\pm$ 100')	79.98	68.94	52.06
Bank ($\pm$ 5^o)	34.91	25.40	30.50

Table 3: Percent-time-within-criteria Scores

Likewise, problems may vary in the degree to which they are amenable to solution by algorithms or algorithmic procedures. A concise taxonomy of algorithms based on these characteristics is presented. The applicability of algorithmic concepts to various types of problems is discussed and illustrated by means of concrete examples.

Brecke, F. H., Gerlach, V. S., & Shipley, B. D., "Effects of instructional cues on complex skill learning," August, 1974. Technical Report No. 40829. Research has indicated the facilitating affect of cognitive pretraining in the acquisition of complex perceptual motor skills. However, precise procedure for generating such verbal instruction is generally unclear if not totally lacking. The present study was undertaken to ascertain the effectiveness of an operationally defined verbal mediator, the instructional cue, on the acquisition of an instrument maneuver flying skill. Eleven subjects enrolled in the UPT program at Williams AFB were given instruction which contained three levels of instructional cues. Analysis of variance techniques as well as graphic analyses revealed that the instructional cue is both a powerful and effective variable. Results were explained in terms of control theory and information theory.

Experimental work.

Three related lines of endeavor were pursued during Phase III. Central to all of our activity was the continued research concerning the effect of cues and feedback on transfer type tasks. Because of the fact that questions arose concerning the effect of practice during the cognitive pre-training phase of skill acquisition, an experiment was designed to study this variable. A second research thrust was the continued effort to discover more effective and efficient methods of measuring student pilot flight performance. The third line of research centered on the study of algorithms as a tool for the instructional designer whose responsibility it is to improve flying training procedures and techniques.

The primary objective of the research conducted during Phase III was to increase knowledge concerning the role of verbal cognitive pretraining in the acquisition of a complex perceptual-motor skill. We found that it was possible to vary the verbal information administered during pretraining in terms of the variable instructional cue. Three levels of this variable were operationally defined. The results of the experiment confirmed our hypotheses. These results are summarized as follows:

(1) Pretraining which includes instructional cues results in better subsequent perceptual-motor performance than does pretraining which does not include instructional cues.

(2) Pretraining which includes systematically developed cues results in better overall perceptual-motor performance than does pretraining which includes current operational cues.

(3) Pretraining which includes systematically developed cues tends to produce a perceptual-motor performance with less within-group variance.

(4) The effects of instructional cues can be observed in terms of overall performance on all variables or in terms of specific performance differences on individual variables, i.e., it is possible to study the effects of different levels of cues as well as the effects of different cues within a level.

These results are especially remarkable if we consider the fact that subjects were exposed to the treatments only once, that the pretraining was of relatively short duration (Mean time: 5.5 minutes), and that subjects were not required to make overt responses during the pretraining phase. The presence of strong experimental effects in spite of these limitations indicates two things:

(1) The conceptual framework of information theory and control theory which was used in the formulation of the hypotheses and the treatments is highly appropriate in the context of complex perceptual-motor learning.

(2) The variable "Instructional Cue" can be defined both theoretically and operationally within this theoretical framework. It is, therefore, a highly researchable variable and, as the treatment's effects show, a powerful variable.

The signifciantly poorer performance of the group which received no cues can be interpreted as empirical evidence for the hypothesized role of a verbal instructional cue. If a student pilot has some cognitive basis for assigning priorities to the various information sources in the cockpit, he can reduce the total information of the perceptual field and successfully allot his limited processing capacity to those stimuli or sources which are immediately relevant to the control task of the system. In the absence of instructional cues, the only alternative for the student pilot is a trial-and-error process which is (as revealed by our experimental protocols over eight trials) quite inefficient when the learning task is as complex as the one used in this experiment.

This interpretation is strengthened by our finding that systematically developed cues are more effective than current operational cues. Systematic cues were explicitly designed to reduce the information processing load of the pilot. Current operational cues, on the other hand, do not originate from a logically coherent conceptual framework but emerge as private idiosyncracies. As such they have some empirical validity, but the validity is not generalizable; it remains idiosyncratic. What "works" for the instructor pilot may or may not "work" for the student. The significantly smaller variance exhibited by the systematic cues group shows clearly that such cues are less idiosyncratic determinants of IP's behavior than are the current operational cues.

The finding concerning the differences in maximum altitude is especially significant in this context. IPs in the SC group received the highly specific cue, "At the leadpoint . . . stop the altimeter by lowering your pitch." The altitude curves for this group stop increasing at 15,900 feet, which is exactly the leadpoint. It may be inferred that this inappropriate behavior is a consequence of the instructional cue,

which is, therefore, an extremely effective cue; unfortunately, it is also inappropriate or dysfunctional. This suggests that the design procedures and criteria (see Appendix C) used for the development of systematic cues may be powerful, but they are not a panacea--at least not yet.

The cue mentioned above (as well as other cues--for example, the cues concerning the perceptual reference on the attitude indicator) led to behavioral effects such as reduction of variance. This phenomenon was clearly discernible in the data, especially in their graphic form. Other cues which appeared equally specific or useful a priori did not lead to any systematic and/or perceptible effects. This suggests that cues which are judged as functional may be differentially effective as mediators of behavior. Further research needs to be conducted to determine which characteristics of instructional cues relate to their effectiveness as mediators.

The second objective of this study concerned the generation and validation of rules for the design of instruction. The maneuver analysis, the rules for generating instructional cues, and the criteria for evaluating these cues represent the tangible output of the study with respect to this objective. As the results of the study show, it is possible to design instructional cues of very high quality when these rules or procedures are employed by subject matter experts and instructional designers. It is also evident from the results that these devices are still imperfect. The major question, however, is whether these design devices--perfect or imperfect as they may be--are applicable to other flight maneuvers. A secondary problem concerns the generalizability to other subject matter expert-instructional designer teams. Both of these questions must be answered on the basis of empirical evidence. In the meantime, however, the assumption that these design procedures are generalizable to other maneuvers finds logical support in the argument that the underlying theoretical framework is certainly broad enough to include all flight maneuvers, or even all situations which involve a human being controlling any kind of apparatus.

Regardless of the answer to these questions, we are still confronted with the question of economy. Designing instruction which incorporates systematically developed cues requires qualified, trained personnel and money. Is it worth the effort and the capital outlay? It certainly would be if we could demonstrate that the use of instructional materials based on systematically developed cues would lead either to savings in instructional time and/or costs or to a better product, i.e., to a more capable novice pilot. Such a demonstration is clearly beyond the scope of the present study. Nevertheless, we can offer some educated speculations based on the conceptual formulations of this study. The generation of systematically developed cues essentially amounts to what has been termed "a proceduralization of technique." This does have some very important advantages in terms of standardization of instruction and in terms of a more objective evaluation of both the student as well as the instructional system. It may, however, lead to a situation which would involve rote learning and mindless regurgitation of a great mass of procedures by the student. It takes little imagination to suspect that

such a situation would do little to provide the student with an opportunity to develop that all-important and very vaguely defined quality called "judgment."

The next research thrust, then, should be a comparison of the mediating effects of maneuver-specific cues with those which are more generic. It may well be that systematically developed generic cues are the most effective and/or efficient mediators for the highly complex perceptual-motor skills which are characteristic of flying.

<u>Phase IV (18 August 1974 through 31 July 1975)</u>

<u>Definition of subject area; research reports</u>

Two technical papers were published during this period:

Shipley, B. D., "Measurement of flight performance in a flight simulator," August, 1974. Technical Report No. 40830. Performance evaluation is an essential part of effective instructional research. The evaluation of complex psycho-motor performances is difficult because they are typically transitory; there is no permanent record, trace, or product after the performance is completed to indicate the characteristics of the performance. The performance of student pilots in the flight simulator or in the aircraft exemplifies the difficulties stemming from the complexity of the task and from the transitory nature of performance. This report describes the results of a methodological study carried out to solve these problems for the purpose of evaluating student pilot performance in a flight simulator. The study was conducted as part of an experiment designed to discern differences in the effectiveness of three different sets of instructional cues used in the student pilots' preflight instructional materials. Methods of collecting, transforming, and analyzing data collected while student pilots were flying a T4-G simulator are discussed and evaluated. Suggestions for applications as well as for further research are offered.

Brecke, F. H., "Cues and practice in flying training," April, 1975. Technical Note No. 50430. Thirty-nine student pilots were randomly placed in one of four experimental groups with seven subjects in an independent control group. The experimental groups received each one of four versions of cognitive pretraining for an instrument flight maneuver (Vertical S-A). Pretraining was varied by type of instructional cue and amount of practice in a 2 x 2 design. Instructional cues were either systematically developed (SC) using a strict procedure based on information theory and control theory or a representative sample drawn from current pilot instruction (CC). Practice was either low with one mastery item or high with three mastery items per cue subset. Subjects in the control group received merely the maneuver objective and supplied their own cues. Groups which received SC cues scored significantly higher than groups which received CC cues in terms of cognitive performance on an immediate posttest ($\underline{p} < .01$) and in terms of perceptual motor performance on six maneuver trials in a simulator ($\underline{p} < .01$). The control group scored significantly higher on perceptual motor performance measures than the groups which received CC cues ($\underline{p} < .01$). The practice variations led

to significant differences in posttest time ($p < .05$) but not in perceptual motor performance. It was concluded that transfer to perceptual motor performance is a function of the type of instructional cue administered during cognitive pretraining. The results also suggest that self supplied cues may be more economical instructional stimuli than either systematically developed or currently operational cues.

Experimental work.

The measurement problems involved in assessing the effects of cognitive variables on the acquisition of a complex perceptual motor skill have been described above. The lack of reliability which characterized subjective observations of student pilot behavior as well as the inaccessibility of any reliable automated device made necessary an intensive research effort dedicated to the development of sophisticated measurement procedures.

This phase of the project was, essentially, a methodological research endeavor. It was conducted to determine whether complex non-verbal performance in a simulator could be measured (a) during learning, (b) by automated means, and (c) with high reliability and validity.

Performance measurement is an essential part of effective instructional research. The measurement of complex perceptual motor performance is especially difficult because it is transitory. Most peformances leave no record, trace, or product which can be used to study the characteristics of the performance post hoc. This limitation is particularly serious when one needs to observe changes within a performance or between repeated performances.

For example: instructor pilot ratings are commonly used to assess student pilot performances. This procedure is less than adequate, particularly for research purposes, because of intra- and inter-rater differences, and because the details of the performance are lost. The present methodological study was carried out in the context of a concurrent instructional design experiment to find solutions to the problem.

Instructional Experiment. Three groups of Air Force student pilots were given cognitive pretraining in the form of a printed manual and a videotaped briefing. Each subject worked through the materials alone and then performed a sequence of eight trials on an instrument flight maneuver, the Vertical S-A, in a flight simulator. Results supported the research hypothesis that instructional cues are effective mediators during the learning of a perceptual motor task.

The description of the data collection and data processing methods, below, constituted the basis of the methodological study.

Data collection. An analog-to-digital converter was used to change the voltage levels from six simulator electrical signals to binary data. These data were recorded on a cassette tape and later they were transcribed to digital computer tapes for processing on a large scale digital computer.

Performance variables. Values of the following variables were recorded every two seconds: airspeed, heading, vertical velocity, altitude, pitch, power, and elapsed time for each trial.

Data analysis. Special Fortran computer programs were prepared to transform the binary data so that standard computer programs could be used to obtain a variety of descriptive statistics. We then carried out a series of analyses of variance and we produced three different sets of graphic plots.

The measurement procedures made it possible to identify significant effects of the instructional treatments which might well have been overlooked with less discriminating procedures. The graphic plots in particular yielded a dramatic illustration of the sources of these effects.

The objectives of the methodological study were satisfied. The automated methods allowed for the analysis of the data in a variety of ways never accomplished previously to our knowledge. As opposed to instructor pilot ratings and on-line computer summarization procedures, our procedures preserve data which is obliterated or lost in a traditional rating or summary index value. Finally, it appears that such procedures can be applied in a real-time instructional setting because they are neither extremely complex nor costly.

As indicated in the description of Phase III activites, the question of the effect of practice assumed ever-increasing importance. For that reason, the experiment described in Technical Note No. 50430 was conducted. The primary objective was the identification of variables which influence transfer from cognitive pretraining to perceptual motor skill acquisition. The results clearly support the central hypothesis that the direction of transfer is dependent on the type of verbal instructional cues which were learned during cognitive pretraining. Systematically developed instructional cues led to more precise perceptual motor behavior than currently operational cues, which appear to inhibit rather than facilitate performance. The results did not confirm the hypothesis that the amount of cognitive practice would be directly related to the amount of transfer. Variations in the amount of cognitive practice did not result in subsequent variations of perceptual motor performance.

The most significant specific finding of the cognitive phase of the study is the superior posttest performance of groups which had received systematic cues. Subjects in this treatment condition achieved posttest scores which were on the average 17 percentage points above those of subjects who had received current cues. These higher scores were achieved at no expense in terms of time through program. It follows that systematic cues were much more readily retained or, to put it differently, that systematic cues may be considered to be more efficient verbal cognitive mediators than current cues.

The amount of cognitive practice with a given set of cues did not influence posttest scores but it did lead to differences in posttest time. Subjects in the high practice conditions had significantly shorter posttest times than subjects in the low practice conditions.

Since the posttest consisted of a straightforward reproduction of a list of cues, this result shows clearly that the cues were more readily recalled by subjects in the high practice condition. It is important to note, however, that greater readiness of recall does not entail greater precision of recall. Readiness of recall or cognitive availability of cues appeared to be a function of practice, whereas precision of recall varied with the type of instructional cue.

In short, both independent variables resulted in significant cognitive performance differences. The results of the perceptual motor phase of the study show partially corresponding performance differences, indicating partial transfer from cognitive learning to perceptual motor skill acquisition.

The two levels of instructional cues which led to differences in the precision of cognitive performance led to similar differences in the precision of perceptual motor performance. The relatively high and stable performance of the systematic cues groups contrasts initially with the much lower and gradually increasing performance of the current cues groups. By Trial 4 all experimental groups had merged at a performance level which represents a performance ceiling for all but the control group.

These differential performance patterns indicate that systematic cues facilitate perceptual motor performance in a way which permits the learner to perform at or near ceiling performance from the beginning. Current cues, by comparison, initially inhibit performance. This inhibiting effect gradually disappears as indicated by the gradual convergence of the essentially flat performance curves for systematic cues and the steadily ascending curves for current cues. In the absence of a true zero point of transfer effects it is of course impossible to define positive or negative transfer effects in absolute terms. Statements about transfer can, therefore, be made only in relative terms. Thus, relative to current cues, systematic cues are facilitative or show positive transfer effects or, relative to systematic cues, current cues are inhibitory or show negative transfer effects.

The performances of the control groups in the present and in the preceding study (Technical Report No. 40829) add some reference points to these considerations. The control group in the preceding study received merely the maneuver objective and its subsequent perceptual motor performance was at the same level as that of the current cues group. The control group subjects in the present study received the maneuver objective and were asked to write down the steps they would follow in executing the maneuver, which essentially amounts to asking the subjects to analyze the maneuver and to supply their own cues. The control group in the present study performed at or above the performance level of the systematic cues group. This result provides a positive boundary value of transfer with respect to the treatment conditions investigated so far. In relation to this boundary value systematic cues can be considered maximally effective mediators of perceptual motor skill, whereas current cues must be considered to be considerably less effective. The assumption that the direction of transfer is a function of the type of instructional cues is,

therefore, supported at least in relative terms by the results of this study.

The two levels of cognitive practice which resulted in significantly different degrees of cognitive availability of a given type of instructional cues did not lead to the predicted differences in perceptual motor performance. If the hypothesis of a direct relationship between amount of cognitive practice and amount of transfer would have been borne out, the performance differences between systematic cues and current cues would have been smaller for low practice conditions than for high practice conditions. The results did not show any significant performance differences due to practice effects, even though the trial means indicate a tendency towards lower performance levels for high practice conditions.

It is speculated that the failure to find overall significant effects for the practice variable by regular analysis of variance procedures was at least to some extent a consequence of the extreme instability of the T-4G simulator. This instability led to an information processing load which was considerably higher than it would have been if the simulator would have reacted like the real aircraft or the regular training simulator. Evidence to this effect is the fact that all but seven of the 39 subjects indicated that the simulator used in the experiment was "harder to fly" than either the aircraft or the regular training simulator. Increased information processing loads led to the common phenomenon of over-control, which in turn resulted in performance variances high enough to mask out any existing effects of the practice variable.

The high and heterogeneous variances associated with the perceptual motor data of the experimental groups also provide an explanation for the lack of significant correlations between cognitive mastery and perceptual motor performance.

In summing up the outcomes of this study with respect to its first objective, the following statements appear justified:

1. The results show clearly that transfer from cognitive pretraining to perceptual motor learning is affected by the type of verbal instructional cue learned during cognitive pretraining.

2. The results of the study provide a baseline for the investigation of practice as a second independent and manipulable variable of cognitive pretraining. Increased levels of cognitive practice appear to lead to greater cognitive availability of the instructional cues which in turn should lead to distinguishable perceptual motor performance differences.

3. Instructional cue was defined as an independent variable on the basis of a conceptual framework which includes both information theory and control theory. The results indicate that this conceptual framework is highly appropriate in the context of perceptual motor learning.

4. The conceptual framework used in this study also represents a common denominator for the several research approaches to the problem of

the cognitive antecedents of perceptual motor learning which were discussed in Technical Note No. 50430.

The second objective of the study was the discovery and validation of prescriptive principles for the design of perceptual motor instruction. On both counts, in terms of validation of existing design principles as well as in terms of discovery of new design principles, the study resulted in the attainment of the second objective.

The instructional design devices which were used in the preceding experiments were used again in the present study. The same maneuver analysis, the same criteria for the distinction between functional and nonfunctional cues, and the same procedures for cue generation were employed to produce a different type of instructional treatment. In the preceding experiment an approximation of the current standard USAF instructional procedure was used consisting of a prose text and an instructor briefing which was simulated by a TV presentation. In the present study the instructional treatment consisted of programmed instruction without a briefing. The predicted instructional effects were in both cases confirmed by the experimental results which amounts to an empirical validation of the design devices over two types of instructional treatments.

The results of the study also provided empirical evidence for two previously uninvestigated considerations for the design of perceptual motor instruction.

The high practice version of the instructional treatments was created by a straightforward repetition of identical mastery items. This manipulation led on the one hand to a significant decrease of the instructional efficiency of the program and on the other hand to negative attitudes on the part of the learners. The decrease of instructional efficiency was evidenced by the sharp increase of program time without concurrent increase in posttest scores. Evidence for the negative learner attitudes comes primarily from the significantly lower ratings for the instructional treatments which were given by the group which received current cues and high practice. It follows that instructional programs which are designed to provide cognitive pretraining should not incorporate repetitive practice of the type used in this study.

A second consideration for the design of perceptual motor instruction arises out of the performance exhibited by the control group. This group showed a very high performance for a very low investment in terms of cognitive pretraining time and an even lower investment in instructional development. From the standpoint of efficiency the instructional treatment administered to the control group is definitely superior to all other instructional treatments administered in this experiment. An instructional procedure which merely supplies the learner with an objective or with a precise idea of the desired goal performance and enlists the ingenuity of the learner in finding ways to attain this goal performance thus appears to be a more economical way to raise the instructional efficiency of pilot training than supplying the learner with explicit "how-to" cues which are very costly to develop.

The question, "Which one of these instructional procedures should be employed?", is, however, not only an economic question. It touches broader curricular goals as well. If the learner is supplied with an explicit set of instructional cues for each flight maneuver, he is essentially faced with the task of learning sets of procedures, i.e., lists of carefully sequenced sentences or sentence fragments. This may very easily lead to rote learning and mindless regurgitation. Even if that danger can be avoided, which is doubtful, this kind of instructional procedure is hardly conducive to the development of judgment, the ability to analyze flying tasks and the ability to make autonomous decisions. It, therefore, appears that an instructional treatment which offers the possibility of attaining a high level of perceptual motor performance on the one hand and a high level of generic cognitive skills on the other hand would be most advantageous.

The findings of the study are limited in their generalizability to other maneuvers and to other teams of subject matter experts plus instructional designers. Another limitation to generalizability arises from the fact that the present as well as the preceding experiment involved only "one-shot" treatments. Future research should, therefore, extend the instructional design procedures to other maneuvers, use different development teams, and examine the effects of various types of cognitive pretraining over repeated experimental sessions and longer time periods.

III. Publications

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Brecke, Fritz H. Cues and practice in flying training. (Technical Report No. 50430, Project AFOSR 71-2128) Arlington, VA: U. S. Air Force Office of Scientific Research, 1975.

IV. Presentations

Fourteen papers were delivered to conventions and professional meetings. In every instance, AFOSR support was acknowledged.

* Venn Diagrams as Mediators of Rule Learning. Annual Convention of Ammerican Educational Research Association, New Orleans, March 1, 1973.

Algorithms in Teaching and Learning. Annual Convention of the Association for Educational Communications and Technology, Las Vegas, April 12, 1973.

* Algorithms in Structured Learning--A Critical Review. Annual Convention of the American Psychological Association, Montreal, August 27, 1973.

The Effect of Instructional Cues on Learning in a Simulated Environment. Annual Convention of the Association for Educational Communications and Technology, Atlantic City, March 19, 1974.

* Automated Measurement and Analysis of Multiple Complex Dependent Variables. Annual Convention of the American Educational Research Association, Chicago, April 17, 1974.

* Algorithmic Organization in Teaching and Learning: The Literature and Research in Europe. Annual Convention of the American Educational Research Association, Chicago, April 18, 1974.

How Much Flying Can a Pilot Learn on the Ground? Annual Convention of the National Society for Performance and Instruction, Miami Beach, April 20, 1974.

Algorithms: Applications in Instructional Research and Development. Annual Interdisciplinary Conference on Structural Learning, Philadelphia, April 21, 1974.

Exploitation of the Instructional Cue in Flying Training. Air Force Office of Scientific Research/Air Force Human Resources Laboratory Conference, Williams AFB, Arizona, February 21, 1974.

* The Effect of Figural Cues on Rule Learning. Annual Convention of the American Psychological Association, New Orleans, August 30, 1974.

* Algorithms: New Tool for Educational Technology. Annual Convention of the American Educational Research Association, Washington, D. C., March 31, 1975.

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* An abstract of this paper was published in the convention proceedings.

* Instructional Design: Beyond Behavioral Objectives and Criterion-referenced Assessment. Fifth Annual Convention of the Structural Learning Society, Philadelphia, April 6, 1975.

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United States Air Force. Primary flying . . . jet. (Air Training Command Manual 51-4) Washington, DC: Department of Defense, 1970.

Appendix A

Cues per Briefing

SEGMENTS	Briefing No.			1		2		3		4		5		6		7		8	
	Total F + D	F & D		F	D	F	D	F	D	F	D	F	D	F	D	F	D	F	D
A	10	7	3	4	0	0	0	0	1	0	1	1	1	2	0	0	0	0	0
B	36	7	29	0	6	2	4	1	3	1	5	2	2	0	2	1	3	0	4
C	35	11	24	0	2	3	2	1	2	0	3	1	1	1	6	1	7	4	1
D	35	4	31	0	3	0	6	2	6	0	4	0	2	1	2	1	4	0	4
E	29	3	26	0	0	1	1	0	5	0	0	1	2	0	1	1	16	0	1
F	8	0	8	0	0	0	1	0	0	0	0	0	1	0	4	0	2	0	0
Non placeable	1	1	0	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Totals F & D	154	32	121	4	11	6	14	5	17	1	13	5	9	4	15	4	32	4	10

Distribution of Functional and
Dysfunctional Cues
over Briefings

Briefing	% Functional	% Dysfunctional
1	26.6	73.4
2	30.0	20.0
3	22.7	77.3
4	7.7	92.3
5	30.7	69.5
6	21.0	79.0
7	11.1	88.9
8	28.5	71.5
Means	22.3	77.7

Appendix B

The vertical S-A maneuver consists of a series of alternating climbs and descents. Each climb or descent covers 1000 feet of altitude change at a constant rate of 1000 feet/minute. The heading and the airspeed of 160 knots remain constant throughout the maneuver.

Establish a climb or descent at a rate of 1000 fpm. Proper coordination of pitch and power is essential. The lead associated with a descent or climb level-off is used as a starting point for the reversal in vertical direction after each 1000-foot change of altitude. The instant the power is changed, refer to the airspeed indicator and maintain 160 knots during the transition to the climb or descent.

The use of trim increases the ease of aircraft control. A rapid crosscheck is necessary during the changes in vertical direction. You must anticipate the need for a power change before the 1000-foot point is reached because the vertical velocity cannot be stopped in an instant. (51-4)

The vertical S-A maneuver consists of a series of alternating climbs and descents. Each climb or descent covers 1000 feet of altitude change at a constant rate of 1000 feet/minute. The heading and the airspeed of 160 knots remain constant throughout the maneuver.

The maneuver can be partitioned into transitional segments and steady state segments. It begins with (1) straight and level flight followed by a (2) transition into a (3) climb (or descent). This climb is maintained until the lead point for the (4) transition "over the top is reached. This transition leads into a (5) steady state descent which is terminated when the lead point for level-off is reached. The level-off is really nothing else but a (6) transition to SLF at starting altitude.

The initial straight and level portion is used strictly for preparation. Fine trim the aircraft for hands-off flight at 160 knots and keep this trim setting throughout the maneuver. Note the power setting it takes to maintain 160 knots at the assigned altitude (approximately 82% at 15000 ft). Carefully adjust the attitude indicator for level indication. Put the heading to be maintained at the top of the J-2. Deviations will be much easier to spot this way. With these preparations completed the actual maneuver can be started.

Begin the transition into a 1000 ft/min climb by applying power smoothly and fairly rapidly. Watch the airspeed indicator and raise pitch steadily so the airspeed stays at 160 knots. Continue raising the nose until the top of the center dot on the attitude indicator just touches the $+5^{o}$ marker. Look for approximately 93% on the tachs to maintain 160 knots at this attitude.

For the steady state climb hold the dot at $+5^{o}$ on the attitude indicator. Check the VVI (out of the corner of your eye) <u>and adjust for deviations on the attitude indicator</u>. Use small increments, no larger than the width of the black line around the center dot. Adjust for airspeed with small power inputs. Maintain heading and watch for the lead point (10% of VVI = 100 ft).

At the lead point start a smooth and fairly fast power reduction (a little bit past the point where the gear warning horn comes on). Stop the altimeter needle by lowering your pitch. Continue to lower your pitch until the bottom of the center dot on the attitude indicator touches the -5^{o} mark. Hold this picture and check the airspeed. It should take a power setting of about 58% to maintain 160 knots at this attitude.

Again, make small adjustments on the attitude indicator--no larger than the width of the black line to maintain your 1000 ft/min descent. Make small power adjustments. Maintain heading and watch for the lead point.

At the lead point, lead with power, smooth and fairly fast. Stop the altimeter by raising your pitch steadily to level indication. Hold it there and adjust your power by looking at the airspeed indicator first and then at the tachs.

Remember:

- Prepare the aircraft for the maneuver
- Lead with power and fly the airspeed
- Look for the dot touching either the $+5^{\circ}$ or the -5° marker
- Correct for the smallest deviation you can see
    - 1 knot on the airspeed
    - 1 degree on the heading
    - the width of the black line on the attitude indicator
- Never look at the VVI while adjusting rate of climb
- Never look at the tachs while adjusting power

Treatment Objective Only
Manual

The vertical S-A maneuver consists of a series of alternating climbs and descents. Each climb or descent covers 1000 feet of altitude change at a constant rate of 1000 feet/min. The heading and the airspeed of 160 knots remain constant throughout the maneuver.

Treatment Current Cues
Briefing

The vertical S-A is a training maneuver which simulates flight conditions as they might occur during instrument approaches. It is designed to provide you with an opportunity to improve two things:

one: the speed and efficiency of your crosscheck

and two: your aircraft control.

The vertical S-A consists of a series of alternating climbs and descents. From straight and level flight at 160 knots you can start either with a climb or with a descent. In this mission you will always start with a climb. Each climb and descent covers 1000 ft and back down to 15000 ft. Each climb and descent is to be flown at a constant rate: 1000 ft per minute. The heading and the airspeed should remain constant throughout the maneuver.

O.K., here is how you fly the maneuver. We start out with straight and level flight.

You want to hold 160 knots in the entry, O.K.?

So what you do is, you align the J-2 compass straight ahead with 160 knots on the particular altitude we are going to use and add power to the required amount that is recommended in 51-4, 93% plus one knot per 1000 . . . ah . . . plus 1% per thousand feet thereabove.

So, to attain a rate climb of 1000 ft/min, simultaneously increase pitch 1-1/4 bar widths on the attitude indicator while smoothly increasing power to the approximate climb power setting.

Raise it very slowly and hold your 160 knots until you approach the 1000 ft/min on the vertical velocity.

You're crosschecking the attitude indicator, the vertical velocity indicator and the airspeed indicator.

Increase your power a prescribed amount to hold 160 knots. So, we are adding power, letting the nose come up, maintaining 160 knots, stopping the nose at a bar and a quarter nose high for a 100 ft/min.

When we get established at a 1-1/4 bar width nose high and 160 knots, we check the VVI and by that time it should be settled down, should be close to a 1000 ft/min. I wouldn't want to raise the nose more than a bar width and a quarter unless I . . . ah . . . stablizied the VVI on something like 800 ft/min, 900 ft/min, and then raise it very slowly, still keeping constant airspeed and power. Now, when you have fine tuned it for 1000 ft/min, trim the aircraft at this point. Once you get the picture set, trim all the pressure off the stick, by using the trim button on the top of the stick.

After you've gone through 30-45 seconds, you want to start glancing at your altimeter also. Include it in your crosscheck. So we monitor the altimeter and when we get to a 100 feet before 16000, just slowly lowering the nose down to one bar width nose low, crosschecking airspeed, attitude, airspeed, attitude throughout the transition.

You have to pull the power back during this transition also, to maintain your 160 and you should establish one bar width nose low with 160 knots.

Once we reach our stabilized point on the attitude indicator, what we are looking for is a 2-1/2 degree . . . bar width, excuse me . . . change in the pitch on the attitude indicator.

In the descent now, you have to check your tachs to make sure your power is set where you want it. Use back pressure only as necessary to maintain the airspeed at 160. Make very, very slow changes.

When you get back down, you level off and again using your 10%, your lead point, raise the picture on the attitude indicator a bar width and a quarter back to level flight.

O.K., that's all there is to it. Let's go do it.

Treatment Systematic Cues
Briefing

The vertical S-A is a training maneuver which simulates flight conditions as they might occur during instrument approaches. It is designed to provide you with an opportunity to improve two things:

one: the speed and efficiency of your crosscheck

and two: your aircraft control.

The vertical S-A consists of a series of alternating climbs and descents. From straight and level flight at 160 knots you can start either with a climb or with a descent. In this mission you will always start with a climb. Each climb and descent covers 1000 ft of altitude change--from 15000 ft to 16000 ft and back down to 15000 ft. Each climb and descent is to be flown at a constant rate: 1000 ft per minute. The heading and the airspeed should remain constant throughout the maneuver.

The maneuver can be divided into several segments. These segments are of two kinds, some are transitions and some are steady states.

The maneuver starts out with a steady state: straight and level flight. Then comes a transition into a climb. The climb itself is a steady state. After the climb comes the transition over the top from the climb into the descent. The descent itself is again a steady state. It ends in another transition, the level-off to straight and level flight at your starting altitude.

O.K., here is how you fly the maneuver. We start out with straight and level flight. During this portion of the maneuver we prepare the aircraft, get it ready, for the maneuver.

When you are established in straight and level flight, go ahead and fine trim the aircraft for hands-off flight. Leave this trim setting then--don't change it--throughout the maneuver.

Make a mental note of the power setting it takes to maintain 160 knots at 15000 feet. It should be right around 82%.

Adjust your instruments, so you have an easier time using them during the maneuver: Zero out your attitude indicator and put the heading you want to maintain at the top of the J-2.

Start the transition into the 1000 ft/min climb by applying power smoothly and fairly rapidly. Watch the airspeed indicator while you apply power and raise your pitch so the airspeed does not creep away more than one or two knots. Keep on raising the nose until the top of the center dot on the attitude indicator just touches the $+5^{\circ}$ mark. Check your tachs. It should take about 93% to maintain 160 at this attitude.

In the climb you want to hold the top of the dot at $+5^{\circ}$ on the attitude indicator. If you need to make adjustments for your climb rate, make them <u>small</u>--not larger than the width of the black lines--and make them on the attitude indicator. Adjust for airspeed deviations with <u>small</u> power inputs. Maintain your heading by keeping your wings level and look out for the lead point, which is at a 100 ft or 10% of your VVI.

To peak out at 16000 feet and to transition into the descent, you start a smooth and fairly rapid power reduction. Stop the altimeter needle at 16000 feet by lowering your pitch. Continue to lower your nose until the bottom of the dot touches the -5° mark. The gear warning

horn should come on shortly before you reach the descent power setting which is about 58% for 160 knots at this attitude.

In your steady state descent at 1000 ft/min and 160 knots, you want to hold the bottom of the dot at -5° on the attitude indicator. Again, if you need to adjust your rate of descent, make small corrections --the width of the black lines is plenty--and make them on the attitude indicator. Adjust for airspeed with small power inputs. Maintain your heading by keeping your wings level and look out for the lead point.

At the lead point for your level-off, lead with power. The movement must be smooth and fairly rapid. Stop the altimeter needle by raising your pitch smoothly up to level indication. Adjust your power by looking at the airspeed indicator first and then at the tachs.

There are a few points you should keep in mind when you fly this maneuver:

- Prepare the aircraft for the maneuver
- Always lead with power and fly the airspeed
- During the climb and descent, the center dot should touch the $+5^{\circ}$ or -5° mark.
- Correct for the smallest deviations you can see:

    1 knot on the airspeed
    1 degree on the heading
    1 black line on the attitude

- <u>Never</u> look at the VVI <u>while</u> adjusting rate of climb
- <u>Never</u> look at the tachs <u>while</u> adjusting power

O.K., that's all there is to it. Let's go do it.

Treatment Objective Only
Briefing

The vertical S-A is a training maneuver which simulates flight conditons as they might occur during instrument approaches. It is designed to provide you with an opportunity to improve two things:

one: the speed and efficiency of your crosscheck

and two: your aircraft control.

The vertical S-A consists of a series of alternating climbs and descents. From straight and level flight at 160 knots you can start either with a climb or with a descent. In this mission you will always start with a climb. Each climb and descent covers 1000 ft of altitude change--from 15000 ft to 16000 ft and back down to 15000 ft. Each climb and descent is to be flown at a constant rate: 1000 ft per minute. The heading and the airspeed should remain constant throughout the maneuver.

O.K., that's all there is to it. Let's go do it.

Appendix C

Cues Inferred from Air Force Manuals

Cues Inferred from Air Force Manuals[1]

a. Transition from straight and level to constant rate climb:

1. Increase power to 100% and simultaneously adjust pitch on attitude indicator to maintain desired airspeed.
2. A slight amount of back pressure is necessary.
3. If the airspeed is two knots low--to regain two knots adjust the pitch on the attitude indicator to change the vertical velocity by 100 fpm.

b. Transition from constant airspeed climb to straight and level flight:

1. The amount of lead to be used on all level-offs (climbs and descents) is 10% of the vertical velocity indication.
2. As the level-off is started, reduce the pitch attitude by reference to the attitude indicator and adjust power as necessary to maintain desired airspeed.
3. Use power as necessary to maintain the desired airspeed and adjust the pitch attitude to maintain altitude.
4. Trim adjustments will be frequent.

c. Transition from straight and level flight to constant airspeed descent:

1. Reduce power to 65%.
2. Adjust pitch attitude on attitude indicator to establish descent. Only a slight adjustment is necessary.
3. Maintain the desired airspeed during entry.

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[1] Cues for segments a through f are taken from ATCM 51-4 (1 April 70); cues for segments g and h are taken from Air Force Manual 51-37.

4. The vertical velocity indicator is used as an aid in maintaining desired airspeed.

5. Adjust power to maintain desired airspeed and simultaneously adjust pitch attitude for level flight. Do this when you reach lead point.

6. Reset power and pitch as necessary for level flight, using altimeter and vertical velocity indicator.

d. Transition from straight and level flight to constant rate climb:

1. Make a power adjustment to the approximate climb power setting. At the same time, adjust pitch for proper attitude on attitude indicator to maintain 160 KIAS.

2. After vertical velocity stabilizes, readjust pitch on attitude indicator to maintain desired vertical velocity. At the same time, adjust rpm on tachometers to maintain 160 KIAS.

3. Deviation from desired rate of climb on vertical velocity indicates need for change in pitch attitude. Pitch and power corrections must be coordinated closely.

e. Transition from constant rate climb to straight and level flight:

1. Level-off from a rate descent is accomplished in the same manner as from constant airspeed descents.

f. Vertical S-A

1. Procedures for maintaining the descent or climb are exactly the same as those for climbs and descents at a constant rate.

2. Establish a climb or descent at a rate of 1000 fpm.

3. The lead associated with a descent or climb level-off is used as a starting point for the reversal in vertical direction after each 1000-foot change of altitude.

4. The instant the power is changed, refer to the airspeed indicator and maintain 160 knots during the transition to the climb or descent.
5. The use of trim increases the ease of aircraft control.
6. You must anticipate the need for a power change before the 1000-foot point is reached because the vertical velocity cannot be stopped in an instant.

g. Constant airspeed climbs and descents

1. Decide what power setting is to be established and estimate the amount of pitch attitude change required to maintain the airspeed.
2. Pitch and power changes are made simultaneously.
3. Power change should be smooth, uninterrupted, and at a rate commensurate with rate of pitch change.
4. It may be necessary to occasionally cross-check the power indicator(s).
5. While power is being changed, refer to attitude indicator and smoothly accomplish estimated pitch change. Only slight control pressures are needed to establish the pitch change.
6. Very little trim change is required.
7. Airspeed indicator must be cross-checked to determine need for subsequent pitch adjustments.
8. Results of pitch attitude changes can often be determined more quickly by referring to the vertical velocity indicator.
9. Upon approaching desired altitude, select a predetermined level-off lead point on the altimeter.
10. Smoothly adjust power to an approximate setting required for level flight, and simultaneously change the pitch attitude to maintain the desired altitude.

h. Rate climbs and descents

1. Estimate the amount of pitch change required to produce the desired vertical velocity and the amount of power change required to maintain the airspeed constant.
2. Enter climb or descent by simultaneously changing pitch and power by predetermined amount.
3. Cross-check the performance instruments to determine the resultant changes.
4. A cross-check of the vertical velocity will indicate the need for subsequent pitch adjustments.
5. A cross-check of the airspeed will indicate the need for subsequent power adjustments.
6. Rate climb or descent is terminated by using normal level-off procedures when approaching the desired altitude.

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was conducted

The research conducted during this project represents a systematic effort to generate prescriptive statements or guidelines for designing effective training materials and procedures for undergraduate pilot training in both simulated and natural environments. In A series of studies was conducted in which selected dependent variables related to instructional cues, feedback, and transfer were studied as they affected flying training. Results ~~of this series~~ these of studies provided a basis for ~~the~~ developing ~~ment of~~ a model for ~~generating~~ to generate

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instructional cues, based on a set of procedures for an objective task analysis. Further studies were then conducted ~~for the~~ purpose of to demonstrat~~ing~~e the effect of such systematically generated cues. Finally, the generalizability of the effects of such systematically generated cues was observed to determine the effects of amount of practice during cue learning and type of instructional cue.

Concomitantly, ~~a substantial research~~ effort was devoted to the problem of developing objective and automated procedures for measuring complex flying skills in an advanced simulator.